# DRAFT

# DISPERSION MODELING ANALYSIS OF PSD CLASS I INCREMENT CONSUMPTION IN NORTH DAKOTA AND EASTERN MONTANA

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## 1. INTRODUCTION

The provisions of the Prevention of Significant Deterioration (PSD) program were enacted by Congress in the 1977 Clean Air Act (Act). The purpose of this program is to ensure that the air quality in clean air areas does not degrade significantly. To prevent significant deterioration of air quality, Congress set up the principle of only allowing a certain amount of increase in the ambient air concentration over the existing baseline concentration. These allowable increases are known as the "PSD increments." The Clean Air Act provides for three different classes of air quality protection, to reflect varying levels of protection from significant deterioration in air quality. In the 1977 Act, Congress designated a number of "Class I areas" that are to receive special protection from degradation of air quality and, thus, the most stringent PSD increments apply in these areas.

In 1999 North Dakota conducted a draft modeling analysis that shows numerous violations of the Class I PSD increments for sulfur dioxide ($SO_2$) in four Class I areas. Those Class I areas include Theodore Roosevelt National Park, the Lostwood Wilderness Area, the Medicine Lakes Wilderness Area, and the Fort Peck Class I Indian Reservation. In a March 13, 2001 letter to EPA, the North Dakota Department of Health (NDDH) committed to refine this modeling analysis and to subsequently adopt revisions to the State Implementation Plan (SIP) as may be necessary to address the increment violations that may be shown by the revised analysis (see EPA's May 29, 2001 Information Notice for more details, 66 FR 29127). However, in developing a modeling approach to finalize the study, EPA and North Dakota could not fully agree on the appropriate data to be used in the final modeling, or the emissions inputs that should be used in the modeling. This study represents what EPA believes to be a reasonable, but not necessarily the most conservative, methodology to assess the status of Class I increment consumption in North Dakota and eastern Montana, following appropriate EPA guidance and regulatory requirements. We believe this approach also best meets the intent of the increment modeling - to characterize the potential for increment violations under realistic emissions and meteorology conditions. EPA is soliciting public comments on this draft analysis before making a final determination on the status of increment consumption in these Class I areas, and the appropriate regulatory actions that may be necessary to address any PSD increment violations.

In issuing this draft report EPA Region 8 is seeking public input on all aspects of the modeling analysis, however, we are particularly interested in technical comments on the following areas: 1) EPA's characterization of PSD increment-consuming emissions and emissions from sources during the base year periods; and 2) whether the Calpuff model inputs and settings have been selected in a manner that is technically sound and suitable for regulatory purposes.

## 2. Application of Calpuff Modeling System

Consistent with current Interagency Workgroup for Air Quality Modeling (IWAQM) guidance[1] EPA Region 8 selected the Calpuff long-range modeling system to evaluate air quality impacts in this analysis. Calpuff has been proposed nationally by EPA (Federal Register, April 21, 2000, 65 FR 21505) as a refined modeling technique for evaluating impacts from the long range transport of pollutants. The MESOPUFFII model is currently listed in the Guideline on Air Quality Models[2] for use on a case-by-case basis in evaluating long range transport. MESOPUFFII is considered obsolete and has not been proposed as either a preferred or an alternative model in the proposed revisions to the modeling guideline. For this modeling study data were obtained from 25 surface meteorological stations, 6 upper-air stations, and 96 precipitation stations located within and near the Calpuff modeling area. The modeling area, shown in Figure 2-1, covers most of North Dakota, eastern Montana, and small portions of South Dakota, and Southern Saskatchewan. The model was applied individually for each of five years of meteorological data (1990-1994) in accordance with longstanding EPA modeling guidance. Emissons inputs were based on the most recent two years (1999-2000) of source data and, where available, continuous emissions monitoring system (CEMS) data were used to determine appropriate emission rates for use in the modeling. The approach EPA used in characterizing emissions is discussed in Chapter 3.

In North Dakota's 1999 Calpuff modeling analysis, the State conducted a series of model tests to determine appropriate local settings for input parameters/options for which no national default value is available, or which did not seem applicable given local conditions. In addition, the State performed a limited performance evaluation to ensure correct implementation of the model. In this evaluation, model predictions were compared with observed concentrations from two $SO_2$ monitoring sites located in and near Theodore Roosevelt National Park. The performance tests were performed iteratively to determine the effect of adjustments to Calmet/Calpuff model default settings. The State changed a limited number of settings that they judged to be technically sound given local conditions, and generally resulted in improved model agreement with observations. As discussed in the following sections, in this study EPA has adopted many of the changes in default settings that North Dakota has selected in its modeling efforts. To demonstrate the effect these changes would have on overall model predictions, EPA has also performed some modeling runs to predict concentrations when IWAQM recommended defaults are fully implemented. North Dakota's testing suggested that the model performed well, with virtually all of the predicted/observed comparisons falling within a factor of two, with no significant over prediction/under prediction bias evident. These results are consistent with EPA's experience with Calpuff in model evaluation studies in other regions of the United States. However, NDDH's testing of the Calpuff with their model settings was based on data from a

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[1] EPA, 1998 Interagency Workgroup on Air Quality Modeling, Phase 2 Summary Report and Recommendations for Modeling Long Range Transport Impacts. Publication No. EPA-454/R-98-019, OAQPS, Research Triangle Park NC 27711.

[2] EPA 1996, Guideline on Air Quality Models. Code of Federal Regulations, 40 CFR part 51, Appendix W.

Figure 2-1. Class 1 Areas and Major Source Locations

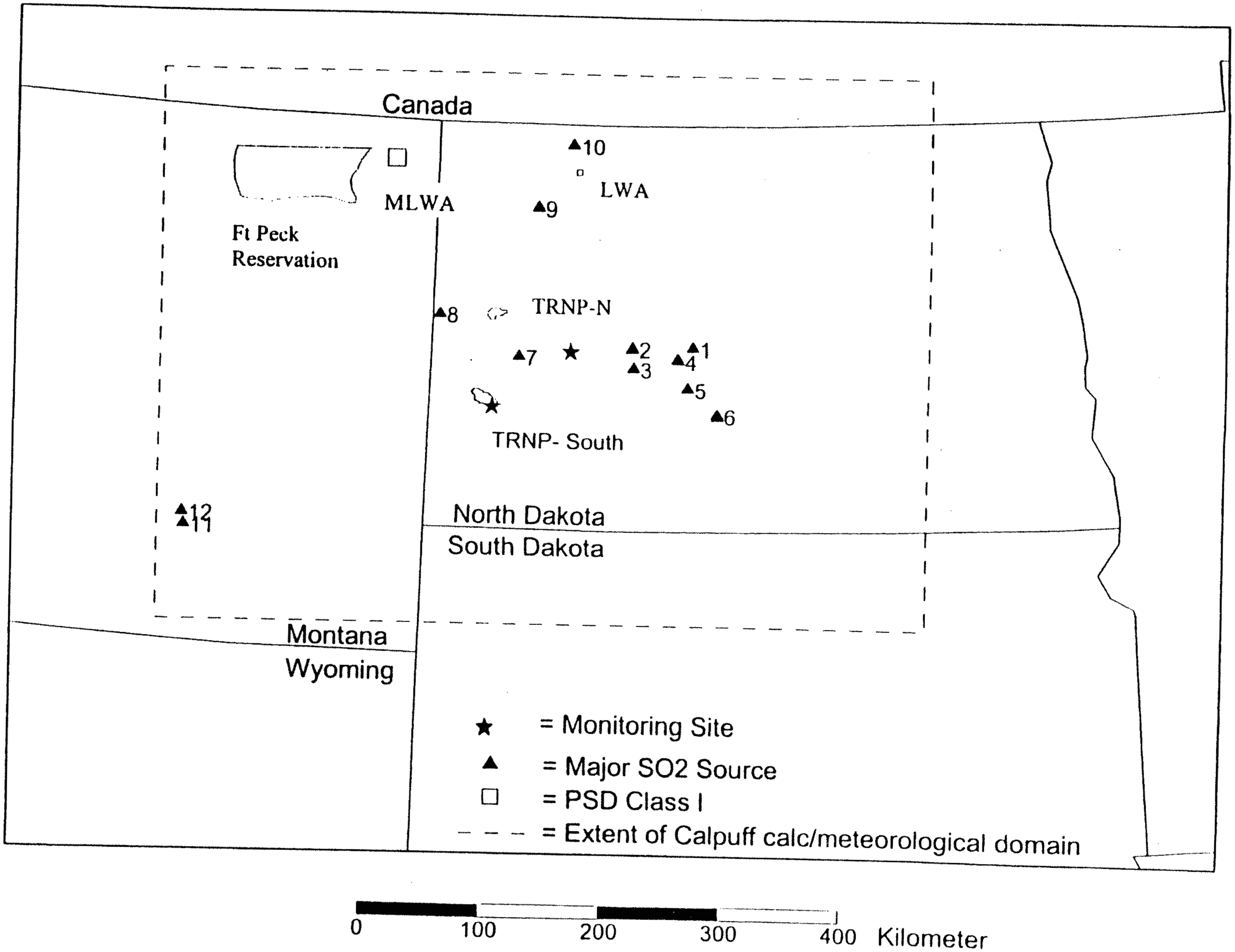

Figure 2-1. Key to Source Locations

1. Coal Creek Station
2. Antelope Valley Station, Great Plains Synfuels Plant
3. Coyote Station
4. Leland Olds Station, Stanton Station
5. Milton R Young Station
6. Heskett Station, Mandan Refinery
7. Little Knife Gas Plant
8. Grasslands Gas Plant
9. Tioga Gas Plant
10. Lignite Gas Plant .
11. Colstrip Station
12. CELP Boiler

| | |
|---|---|
| MLWA | Medicine Lakes Wilderness Area |
| TRNP-N | Theodore Roosevelt National Park- North Unit |
| TRNP-S | Theodore Roosevelt National Park- South Unit |
| LWA | Lostwood Wilderness Area |

very limited number of monitoring sites so that a complete evaluation of the performance could not be conducted. As discussed in Section 4.1, EPA is soliciting public comment on the appropriate model control settings to be used in finalizing the current study.

## 2.1 Meteorological Data Processing With Calmet

EPA was provided with copies of North Dakota modeling files from their 1999 draft modeling study[3]. EPA performed quality assurance testing on the files and determined that the data were adequate for use in dispersion modeling. For the 1999 study the NDDH processed five years of meteorological data (1990-1994) to use with Calpuff. Raw meteorological data was derived from National Weather Service, Federal Aviation Administration, U.S. Military, and Environment Canada observations. EPA has also made several changes to the Calmet IWAQM default settings based on NDDH model evaluation results. These changes are discussed below.

### 2.1.1 Input Data

In establishing the size of the modeling domain, the primary goal was to provide a modeling domain which would encompass new or existing emission sources located up to 250 km from any North Dakota Class I area. The domain extends into eastern Montana, and given the relatively sparse distribution of increment consuming sources in that area, provides sufficient coverage for two eastern Montana Class I areas. The dimensions of the modeling grid are 640 km east-west and 460 km north-south. The extent of EPA's Calmet grid is illustrated in Figure 2-1.

EPA selected a 10 km grid size for this application, compared to the 20 km spacing originally used by NDDH. While a very dense grid is desirable from a scientific standpoint, computer disk storage and model execution time requirements place practical limits on grid cell size. At the 10 km resolution, a single year of Calmet-processed meteorological data requires about 2.2 gigabytes of disk space. Given the gently rolling nature of terrain, relatively uniform land-use characteristics, and the general lack of large terrain features or water bodies large enough to cause persistent, strong local-scale flows, EPA believes a 10 km grid size is adequate for this study.

In the vertical, both the EPA and the NDDH Calmet grid is defined by eight vertical layers. Cell face heights are set at 22, 50, 100, 250, 500, 1000, 2000, and 4000 meters above ground level (AGL). IWAQM does not provide recommendations on this parameter, however, eight layers is consistent with some of the examples and guidance provided by the model developer in documentation for the Calpuff modeling system.

NDDH obtained surface meteorological data for the five-year period 1990-1994 in TD-

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[3] Calpuff Class 1 Area Analysis for Milton R Young Generating Station, North Dakota Dept of Health, May 24, 1999

1440 format from the National Climatic Data Center (NCDC). Data were obtained for 25 stations (National Weather Service, Federal Aviation Administration, U.S. Military, Environment Canada) located within or near the NDDH Calmet grid. EPA has used these same data sets in the current study, including modifications made to the data sets by NDDH described below.

In the processing of the above data NDDH's 1999 efforts found that some adjustments to the surface data files were required before Earth Tech programs METSCAN and SMERGE could be applied. Stations other than first-order National Weather Service (NWS) stations were missing opaque cloud cover for the entire five-year period. Based on a comparison of total and opaque cloud cover in the first-order NWS data sets, the NDDH developed an objective scheme to extrapolate opaque from total cloud cover. This scheme was coded into a computer program (TOT2OPQ) and applied to all surface data sets with missing opaque cloud cover.

In the 1999 study, NDDH followed EPA recommendations in data editing to account for missing data (ceiling height, wind, pressure, temperature, relative humidity). Substitutions were made if data elements were missing for one or two consecutive hours. Except for opaque cloud cover, substitutions were not made for longer missing periods (Calmet ignores stations with missing data). NDDH coded the EPA substitution scheme into a computer program (SUB144) and applied it to all surface data sets. Earth Tech's (the model developer) program METSCAN was next applied to scan each data set for missing or unreasonable values, and appropriate edits were made. Earth Tech's program SMERGE was applied to merge individual station data sets into a single input file (SURF.DAT) compatible with Calmet.

NDDH obtained upper-air meteorological data for 1990 through 1994 from the National Climatic Data Center, and precipitation data was obtained from Earth Info, Inc (Boulder, CO). Data were obtained for six upper-air stations and 96 precipitation sites located within or near the modeling domain. EPA used the same upper air and precipitation data files in the current study as NDDH employed in their original study. NDDH's data processing procedures for both the upper air and precipitation data are discussed in their 1999 report.

Most of the terrain elevation and land use data required by Calmet were originally downloaded by NDDH from the United States Geological Survey (USGS) internet web site. Grid cell terrain elevations were derived from 1:250,000-Scale Digital Elevation Models (DEM) and land use data were derived from 1:250,000-Scale Land Use and Land Cover (LULC). The geophysical file was generated based on Calmet default land use parameters, and the State's original 20 km gridding was reprocessed for this study to a 10 km grid to be consistent with the computational grid. Because of the relatively large modeling domain, the grid system, meteorological data, and geophysical data were fit to Lambert conformal mapping to account for the earth's curvature.

### 2.1.2 Calmet Code Revision

As noted above, in the original 1999 NDDH application of the model and in subsequent tests of year 2000 data, Calmet was tested to determine technically appropriate settings for control file options and parameters. For testing purposes, the Calmet software was modified to optionally output Surfer-compatible coordinate files (XYZ files) for winds (all levels), stability class, and mixing height for the entire Calmet grid for a selected time frame, in order to plot the horizontal distribution of these variables to better judge the appropriateness of Calmet's processing. A Surfer script was prepared to "mass produce" hourly plots of these three parameters for the selected time frame (usually 24 to 48 hours).

The NDDH examined several episodes of plotted wind vectors, stability classes, and contoured mixing heights, with emphasis on episodes (1990-1994 data) where winds might direct significant source emissions toward Class I areas. Episodes included cases with frontal passage or other wind shifts. During the iterative testing process, Calmet control file settings were individually and systematically adjusted primarily for wind and mixing height parameters. Parameters were adjusted so that plotted fields converged to a realistic and relatively smooth appearance. Output wind fields were examined to ensure that spatial variations due to frontal passage and terrain effects were reasonable, and to ensure a realistic transition from surface through upper-level winds.

One issue NDDH noted during the testing of Calmet was a chronic discontinuity between surface and upper wind levels. To mitigate this problem, the option to extrapolate surface wind observations to upper layers was deployed, using similarity theory (Option 4 in the model) and layer-dependent biases. Calmet Version 5 extrapolates surface winds both for setting the initial guess field, and for introducing observations in the Step 2 wind field. Unfortunately, the model utilizes the bias factors for the initial guess field only. The Step 2 vertical extrapolation has equal effect through all upper layers. The NDDH felt this was unrealistic because resultant upper layer wind fields reflected anomalous surface-layer (low-level) perturbations consistently, upward through all upper layers, even in the top layer (4000m). It was felt that such low-level features should dampen with height and not extend up into the middle troposphere. In other words, the Step 2 vertical extrapolation essentially undid the effective Step 1 (dampened) vertical extrapolation of the wind fields. Therefore, the NDDH modified the Calmet code to simply eliminate the vertical extrapolation in Step 2, resulting in a more realistic transition from surface to upper layers. EPA believes this relatively minor change to the code is technically sound for this application in view of the NDDH test results. The NDDH revised version of Calmet is available in electronic format from EPA Region 8. Note that except for the change noted above the Calmet software EPA used in this analysis is identical to the version (Version 5.2, level 000602a) available on the EPA ttn-SCRAM website. The revised source code was recompiled with a Lahey Fortran 95 compiler, which provides faster model execution time than the existing software.

### 2.1.3 Calmet Model Control Settings

Calmet was executed with surface data, upper-air data, precipitation data, and geophysical data as described previously, and with control file options/parameters generally established by published IWAQM guidance. As noted earlier, alternative settings were used in some cases where local testing of the model indicated an alternative setting is more appropriate. A listing of the most significant control file settings used by EPA are summarized in Table 2.1.3-1, and a listing of non-IWAQM settings used by EPA are shown in Table 2.1.3-2. The complete EPA Calmet input control file is available in electronic format from EPA Region 8.

**Table 2-1**
**Calmet Control File**

| Parameter/Option | Value |
|---|---|
| No. surface stations | 24 |
| No. upper-air stations | 6 |
| No. precip stations | 96 |
| No. X grid cells | 64 |
| No. Y grid cells | 46 |
| No. vertical layers | 8 |
| Diagnostic wind module | Yes |
| Use O'Brien procedure | No |
| Extrapolate surface wind observations | -4 |
| RMAX1 | 300 km |
| RMAX2 | 1200 km |
| TERRAD | 100 km |
| R1 | 125 km |
| R2 | 100 km |
| No. barriers (NBAR) | 0 |
| MNMDAV | 8 |
| ILEVZI | 4 |

**Table 2-1**
**Calmet Control File**

| | |
|---|---|
| Minimum overland mixing height | 50 m |
| Maximum overland mixing height | 4000 m |
| TRADKM | 500 km |
| SIGMAP | 100 km |

**Table 2-2 Non-IWAQM Settings used by EPA in Calmet Control File**

| Parameter | IWAQM | Current EPA Study |
|---|---|---|
| IKINE | 0 | 1 |
| BIAS (Values for each vertical level) | 0,0,0,0,<br>0,0,0,0 | -1.0, -0.9, -0.7, 0.0<br>0.5, 1.0, 1.0, 1.0 |
| LVARY | F | T |
| MNDAV | 1 | 8 |
| ILEVZI | 1 | 4 |
| ZIMAX & ZMAXW(over water) | 3000 m | 4000 m |

The reason EPA selected each non-IWAQM setting in the current study is discussed below:

IKINE - The inclusion of kinematic effects reduced predicted concentrations by about 10 percent at the two monitoring sites providing somewhat better agreement between Calpuff results and monitored observations. There is a risk that use of this option will create unrealistic wind fields.

BIAS(NZ) - The IWAQM recommendation provides neutral bias (between surface and upper-air data) for all vertical layers. The meteorological data set used in the modeling includes data from a large number of both surface and upper-air sites. Given the relatively rich set of measured data, both at the surface and aloft, it does not seem reasonable to assume equal weighting of upper-air wind data with surface data at the lowest level, and to assume equal weighting of surface data with upper-air data at top levels.

LVARY - This option was selected to ensure that at least one station would always be available for model input.

MNMDAV/ILEVZI - NDDH found that IWAQM default values for these parameters, relating to spatial averaging of mixing heights, produced unrealistic spatial variations in the mixing height field. Severe gradients (bull's eyes) in mixing height were observed in the immediate vicinity of meteorological stations, and the selected values in these input parameters smoothed the gradients. The overall area-wide average value of mixing height was not significantly affected by this change.

ZIMAX/ZIMAXW - In the western part of the upper Great Plains maximum summertime mixing heights frequently exceed the default value of 3000 m. A value of 4000 m was selected based on reported maximum mixing heights for this region (Holzworth, 1972)[4].

### 2.2 Calpuff Application and Postprocessing

EPA has generally used IWAQM default values in selecting Calpuff control file settings, unless local conditions indicate that alternative settings are more appropriate. In addition to selection of the most technically sound control settings, model execution time was a factor in selecting certain parameters. EPA reviewed the results of the NDDH testing discussed below and has initially selected Calpuff control file settings that are very similar to those used in the NDDH study.

#### 2.2.1 Receptor Locations

A total of 49 receptor locations were selected for calculating concentrations in the 4 Class I areas in North Dakota and Montana. Maximum receptor spacing in the North Dakota Class I areas is about 5 kilometers. Receptor coverage for Medicine Lake and Fort Peck Class I areas was less dense because they are located further from the largest contributing sources, and local minor source emissions contributions could not be fully accounted for. Given the distances of the largest contributing sources from these Class I areas (150 - 300 km), concentration gradients would not be expected to be significant within individual areas, thus receptor coverage appears to be adequate. Additional receptors would also have the disadvantage of slowing Calpuff execution times. The receptor numbers correspond to receptor locations in the following Class I areas: Receptors 1 - 22, TRNP South Unit; Receptors 23 - 38 TRNP-North Unit; Receptor 39,

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[4] Holzworth, 1972, Mixing Heights, Wind Speeds, and Potential for Urban Air Pollution Throughout the Contiguous United States, EPA, Office of Air Programs Publication AP-101

TRNP Elkhorn Unit; Receptors 40 - 44, Lostwood Wilderness Area; Receptor 45 Medicine Lake Wilderness; and Receptors 46 - 49 Fort Peck Reservation.

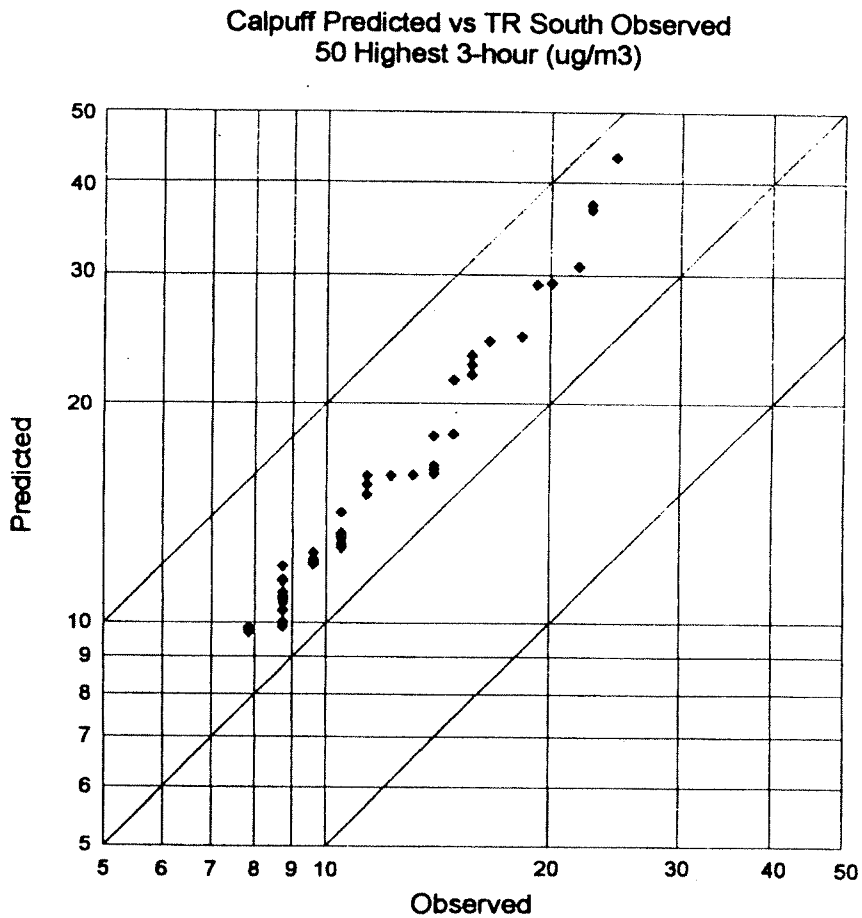
### 2.2.2 Calpuff Evaluation and Model Control Settings

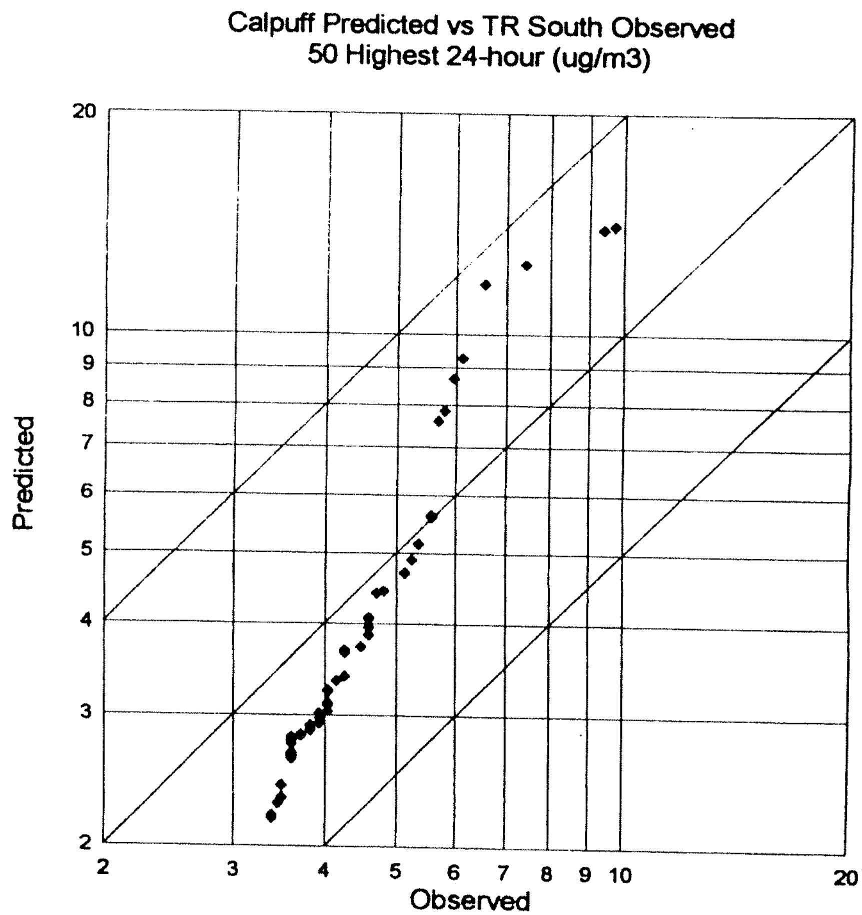
To determine the effectiveness of selected Calpuff control file settings, as well as the utility of the Calmet/Calpuff implementation in general, NDDH conducted a limited model performance evaluation, using data from two monitoring sites located in or near Theodore Roosevelt National Park. The NDDH Calpuff evaluation is described in the NDDH 1999 Calpuff Class I Modeling Study. Calpuff was tested in the NDDH study using Calmet meteorological data files prepared as described in Section 2. In general IWAQM default values were used in selecting Calpuff control file settings when other information was not available. Testing was conducted primarily to determine sensitivity of results and execution time associated with parameters/options for which default values were not provided. The goal was to achieve a technically competent implementation of the model while maintaining reasonable execution time. Calpost was applied to summarize Calpuff hourly output. Values for selected Calpuff control file parameters/options were individually and systematically varied to determine effect on results and execution time. NDDH conducted testing, for example, to determine sensitivity of results to deployment of puff splitting, terrain effects, PDF (Probability Distribution Function) for convective conditions, and partial plume penetration of elevated inversion. All seemed to have some effect on model results but, with the exception of puff splitting, none of these options caused a significant execution time penalty. Therefore, as in North Dakota's 1999 analysis, EPA has concluded it is appropriate to deploy all of these options for modeling major sources. Given the number of minor sources (principally oil and gas sources) along with execution time considerations, puff splitting will not be deployed for minor sources.

NDDH has continued to test Calpuff performance using year 2000 emissions and meteorology data.[5] The evaluation of Calpuff performance for Year 2000 data at Dunn Center and TRNP South Unit monitoring sites still indicates the modeling system performs relatively well, when implemented using IWAQM control file settings as modified by NDDH. In these latest results, shown in Figure 2-2, predicted-to-observed ratios (unpaired in time) for the fifty highest predicted/observed concentrations fell within the factor-of-two criteria suggested by EPA guidance, and did not exhibit a strong systematic bias toward underprediction or overprediction. EPA has some concern, however, that the 24-hour averages at TRNP South Unit are underpredicting concentrations, particularly for rankings lower than the top ten values. For increment consumption modeling, the limiting concentrations (i.e. the highest second-high predicted concentration for each year modeled) would not necessarily occur under conditions that

[5] NDDH Draft Report, Evaluation of Calpuff Model Performance Using Year 2000 Data, November 2001

# Figure 2-2




Source: NDDH Draft Report, Evaluation of Calpuff Model Performance using Year 2000 Data, November 2001 lead to the top 10 ranked values shown in the figure. This is due to the fact that increment analysis involves modeling a limited number of emitting sources in the region, while NDDH's performance testing of the model necessarily involved modeling all major sources in the region.

EPA has reviewed the NDDH testing and evaluation results along with the latest IWAQM guidance and selected the Calpuff control file settings summarized in Table 2-3. Non-IWAQM settings are shown in Table 2-4 and the reasons for their selection are discussed below. In the current draft analysis EPA has generally used the same NDDH model settings as were used in the Draft 2000 model evaluation study discussed above, despite some concerns about possible model underpredictions. A test run using regulatory default model settings has also been done and these results are discussed in Section 4.1.

**Table 2-3 Calpuff Control File**

| Parameter/Option | Value |
|---|---|
| No. chemical species | 5 |
| Vertical distribution near field | 1 |
| Terrain adjustment method | 3 |
| Subgrid-scale complex terrain | 0 |
| Slug model | No |
| Transitional plume rise | Yes |
| Stack tip downwash | Yes |
| Vertical wind shear | No |
| Puff splitting | Yes |
| Chemical mechanism | 1 |
| Wet removal | Yes |
| Dry deposition | Yes |
| Dispersion coefficient method | 2 |
| Partial plume penetration - elev. inversion | Yes |
| PDF used under convective conditions | Yes |
| CSPEC | $SO_2$, $SO_4$, $NO_x$, $HNO_3$, $NO_3$ |
| Chemical parameters - dry gas deposition | Default |